APPENDIX A
CONSIDERATIONS IN SELECTING PARTICLE SIZE CUT POINT FOR FINE PARTICLES

An important decision relating to the choice of indicator is the choice of measurement which in a sense serves as an operational definition of fine particles. The CD concludes that the minimum of mass between the fine and coarse modes lies between 1 and 3 μm, and that the scientific data support a cut point to delineate fine particles in this range (CD, Chapter 3-5). Because of the overlap of fine and coarse particles in this intermodal region, specific cut points are only an approximation of fine particles. Thus, the decision within this range is largely a policy judgement. Although most fine particle (accumulation mode) mass is below 1.0μm, some hygroscopic particles in conditions of high relative humidity may gain water and grow above this size. However, energy considerations normally limit coarse mode particle sizes to greater than 1.0 μm in diameter (CD, 3.1.2).

The main policy choice centers on two options: $PM_{2.5}$ and PM_1. Staff recommend the three primary factors to consider in selecting a cut point are consistency with health data, potential for intrusion of mass from the other mode, and availability of monitoring technology.

From a public health perspective, use of a $PM_{2.5}$ cutpoint will result in the capture of all of the potential agents of concern in the fine fraction. For example, the cutpoint of $PM_{2.5}$ captures most sulfates, acids, fine particle metals, organics, and ultrafine particles and accounts for most of surface area, and particle number. Although the CD outlines some conditions (e.g., relative humidity near 100 percent) under which it is possible that hygroscopic particles may grow above 2.5μm, use of the $PM_{2.5}$ cutpoint is still better at capturing the constituents of concern than PM_1.

$PM_{2.5}$ has been measured directly in many health studies as described in the CD and Chapter V, Section F above. Significant associations have been reported between $PM_{2.5}$ concentrations and mortality, hospital admissions, cough, upper respiratory infection, lower respiratory infection, asthma status, and pulmonary function changes.

$PM_{2.5}$ measurement technologies are widely available and have been in routine use in the field since the early 1980s. For example, the EPA AIRS database contains $PM_{2.5}$ data from the Inhalable Particle Network (1982-1984), the IMPROVE network (1987 - present), and the NESCAUM network (1988- present). In addition, the California Air Resource Board (CARB) dichotomous sampler network has been collecting $PM_{2.5}$ data routinely since 1980, and many other special studies measuring $PM_{2.5}$ have been conducted across the country. Furthermore, dichotomous samplers allow the coincident measurement of PM_{10} and $PM_{2.5}$, increasing the certainty of comparability between the two measurements.

Measurement of fine particle mass using a 1 μm (PM_1), on the other hand, has not been used in health studies primarily due to lack of available monitoring data. Comparisons between PM_1 and other measurements that were used in the health studies (e.g., PM_{10}) are also not widely available due to lack of available PM_1 monitoring data. Furthermore, PM_1 may not capture as much of the hygroscopic substances such as sulfates which health studies report as having statistically significant associations between sulfate measurements and endpoints including increased mortality and hospital admissions.

PM_1 sampling technologies have been developed and some limited validated data are available from locations such as Phoenix, Arizona. However, the PM_1 samplers have not been widely field-tested to date.

Proponents of the PM_1 option are concerned that the intrusion of particles generated by grinding or crushing (i.e., coarse mode particles) into the daily $PM_{2.5}$ measurement could create spurious NAAQS exceedances. Given the lack of PM_1 data currently available, it is difficult to determine how much intrusion might occur or what areas might be affected during the implementation of a $PM_{2.5}$ NAAQS. The available data show that typically only 5-15 percent (on the order of 1 to 5 $\mu g/m^3$) of the $PM_{2.5}$ mass is attributable to soil-type sources even in dusty areas such as San Joaquin Valley, California, and Phoenix, Arizona. However, this percentage may increase during events such as high winds.

The staff judges that in typical urban areas, the potential for this type of intrusion may be smaller, but without sufficient data these determinations remain very uncertain. A sharper inlet for the Federal Reference Method may help to minimize the intrusion of coarse mode

particles into the $PM_{2.5}$ measurement. Although intrusion of coarse mode particles into daily $PM_{2.5}$ measurements is not anticipated to be significant in most situations, if in light of more data a problem is identified, this issue might be better addressed on a case-by-case basis in the monitoring and implementation programs.

Finally, the staff concludes that $PM_{2.5}$ measurements are more appropriate than some of the measurements historically used in the epidemiological studies (e.g., BS, CoH) although these measurements have been useful in advancing the state of scientific knowledge of particle effects. British Smoke (BS) readings vary more with darkness of particles (i.e., carbon content) than with mass, making associations with mass highly site- and time-specific. The BS method emphasizes control of primary elemental carbon emissions; however, elemental carbon is a minor contributor to fine and total mass in current U.S. atmospheres. Furthermore, lack of consistent relationships between BS reflectance and PM mass measurements diminishes one of the major advantages: BS is not related to the available quantitative health data from U.S. cities with as much certainty as the $PM_{2.5}$ mass measurements although BS is used in many other countries. Using a similar principle to BS, the principle of coefficient of haze (COH) is that visible light is transmitted through (or reflected from as in the case of BS) a section of filter paper before and after ambient air is drawn through it. Thus, COH associations with mass are also highly site- and time-specific.

Thus, because of the consistency with health data, small potential for intrusion, and availability of monitoring technology and existing air quality database, the staff judges that the $PM_{2.5}$ measurement is more appropriate for regulatory purposes than PM_1, or historical measurements such as BS or COH.

APPENDIX B

MEASUREMENT METHODS FROM EPIDEMIOLOGY STUDIES

The CD and Chapter V of this Staff Paper summarize health studies which have reported associations between various indicators of PM and health effects. The main mass concentration indicators are TSP, PM_{10}, and $PM_{2.5}$. In addition to $PM_{2.5}$ mass measurements, fine particles have been measured in the U.S. and abroad using a variety of techniques including British or black smoke (BS), coefficient of haze (COH), carbonaceous material (KM), and estimates from visibility measurements (CD, Section 4.2.8).

Studies have also reported associations between health effects and exposure to fractions found predominantly in the fine fraction such as sulfate ($SO_4^=$) and strong acidity (H^+). The CD describes measurement techniques in detail; this section highlights relevant information about other indicators of fine particles (i.e., BS, COH, and KM).

In the past, it was noted that visibly black plumes were emitted by industrial sources; thus, light absorption was adopted as a measure of PM pollution (Chow, 1995). Measurements of the optical properties of particles may be related to gravimetric mass measurements on a site- and time-specific basis with on-site calibrations.

BS preferentially measures elemental carbon particles found in the fine fraction (CD, Section 4.2.8; Baily and Clayton 1980). In addition, the BS inlet design, taken together with its other operating parameters, restricts the size of particles that are sampled. For example, it has been shown in wind tunnel tests that the best estimate of the cut point for BS is 4.5 µm (CD, page 4-52; Waller, 1980; McFarland, 1979). Most particles larger than the cut point of 4.5 µm are either rejected at the inlet or lost in the inlet line (U.S. EPA, 1982a). Furthermore, the BS reading varies more with darkness of particles (i.e., carbon content) than with mass, thus making associations with mass highly case-specific. Because elemental carbon is found predominantly in the fine mass (less than 1.0 µm range), variations in BS are more closely related to fine mass and unlikely to be sensitive to coarse mode particles (NAS, 1980; U.S. EPA, 1982b).

Using a similar principle to BS, COH measures visible light transmitted through (compared to reflected from in the case of BS) a section of filter paper before and after

ambient air is drawn through it. The amount of light transmitted is measured by a photocell (Chow, 1995; Fairley, 1990). In addition, this sampler uses a funnel inlet and a small diameter transport tube nearly identical to the BS sampler. Although the two samplers operate at different flow rates, the particles reaching the filter tape could be expected to have a size range similar to that of the BS instrument (U.S. EPA, 1982a, see Figure 3A-12).

Prior to the 1980s, PM was measured in California by optical reflectance of particles collected on a sample tape (KM). Similar in principle to BS, KM has been shown to be closely related to elemental carbon content in Los Angeles (Kinney and Özkaynak, 1990). Similar to BS, KM is also a fine particle measurement.

Visibility measurements can also be used as a reasonable surrogate to estimate fine particle concentrations because the extinction coefficient is directly related to fine particle mass (CD, page 6-216).

APPENDIX C

PM_{10} NATIONAL CONCENTRATION MAPS AND DEFINITIONS OF REGIONS

Current U.S. PM_{10} levels are illustrated in Figures C-1 and C-2. Figure C-1 shows the fourth highest 24-hour PM_{10} concentration recorded in a county and Figure C-2 depicts highest annual mean PM_{10} concentration using 1992 to 1994 AIRS data in each county for which data completeness criteria were met. Counties not represented with a monitor are left blank.

The following methods were used to calculate the values depicted in the maps. The current single exceedance form of the PM_{10} daily standard allows for an average of one exceedance per year over a three-year period. Thus, the fourth highest concentration is of interest because this value is used to determine attainment with the current daily standard. Seven hundred and twelve counties met the data completeness criterion of at least 75 percent complete data for the period 1992 to 1994. For these counties, all daily concentrations were ordered largest to smallest and the fourth highest PM_{10} concentration was determined for each site. If a county had only one site, then the fourth highest concentration for that site was reported. If a county had more than one site, the site with the maximum fourth highest concentration was used to represent the county.

Figure C-2 shows the maximum annual mean concentration in each county over the three-year period using an average weighted by calendar quarter. Three hundred and eighty counties met the 75 percent data completeness criterion by quarter for 1992 to 1994. Means were calculated for all four calendar quarters for each year in the 3-year period and annual values were calculated based on the quarterly means. The three yearly means were then averaged to obtain one value for each site. If a county had only one site, then the annual mean for that site was reported. If a county had more than one site, the site with the maximum annual mean was used to represent the county.

Figure C-3 shows the regions of the country used in some air quality analyses. Note that state boundaries were used except that California and Texas were split.

Figure C-4 illustrates that a total of 87 different sites reported $PM_{2.5}$ data to AIRS from 1983 to 1993. Over the 11 year period, less than 50 sites reported data to AIRS in any given year. Additional special studies have also monitored $PM_{2.5}$, but these data are not reported in AIRS.

Figure C-1.

Figure C-2.

Figure C-3. Regions Used in Air Quality Analyses in this Staff Paper